ENHANCED NUTRIENT SUPPLY TO NORWEGIAN COASTAL WATERS: EFFECTS ON GROWTH OF SCALLOPS AND BLUE MUSSELS

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ABSTRACT

An experiment including an enhanced nutrient supply to coastal waters was performed during 1996-1999 in a landlocked bay, Hopavågen, located in Central Norway. The aim of the study was to quantify effects of the nutrient enrichment on the food web structure and growth of blue mussels *Mytilus edulis* and scallops *Pecten maximus*.

INTRODUCTION

Hopavågen has a surface area of 27 ha, a total volume of 5.4 mill m^3 and a mean depth of 20 m. The volume of euphotic waters is estimated to be 3.7 million m^3, which corresponds to 68% of the total volume. Due to a narrow inlet, the tidal range in Hopavågen is limited to 0.3–1.0 m, compared to 0.8 – 2.3 m in the coastal waters outsideof the bay. Daily water exchange in the bay averages 0.61±0.22 mill m^3 or 0.11±0.04 % of total volume d^{-1}, corresponding to 19% of the productive waters d^{-1}.

MATERIALS AND METHODS

In the first 2 yr of the investigation, 1996 and 1997, physical, chemical and biological data were provided for an undisturbed situation. From early May to mid October 1998 and 1999 nutrients (phosphorus, silicate, and nitrogen) were added during the early tide period with inflowing water to the bay, corresponding to approximately two additions of nutrients daily. The addition of nutrients in 1998 corresponded to 0.4 µg phosphorus L^{-1} d^{-1}or an estimated 100% increase in the phosphorus supply to the bay. The molar ratio for N:Si:P was 15:5.4:1. In 1999 the addition of phosphorus was increased to 0.8 µg P L^{-1} d^{-1}, and the molar ratio of N:Si:P was close to 16:8:1.

Data on growth of scallops and blue mussels are available for 1997 and for the first year nutrients were added, 1998. In the former year, scallops (40 mm) and blue mussels (45 mm) were placed in polyethylene baskets at three different depths and two different depths, respectively, in the central area of the bay. The growth of the shells was followed for 9 months (May 1997-February1998). During the period June 1998–April 1999, the growth of scallops (25 mm) and blue mussels (40 mm) was followed at 2 and 10 m depth at four different sites in the bay and at a control station (Værnes) in a fjord about 1 km from the inlet of Hopavågen. Growth was measured as increase in shell height (SH). In 1998 the content of shell tissue (wet weight, dry weight and ash free weight) of blue mussels and scallops was measured at the end of the growth period.

RESULTS

Physical measurements revealed a 4-5 C higher temperature at 10 m depth in the late summer period (August and September) in 1997 (18 C) compared to 1998 (12 C). The temperature of the surface layer reached 20 C in early September 1997, compared to about 15 C in the following year. The salinity was in the range of 31 – 33‰ in both years, and the water current at 10 m at the four stations in Hopavågen varied from 1.1 – 1.8 cm s^{-1}.

The mean chlorophyll *a* content (June-September) was in 1996 and 1997 estimated to be 2.1 µg l^{-1} and 1.8 µg l^{-1}, respectively. About 80% of the mean chlorophyll *a* content was in the fraction less than 20 µm in both years, and particles less than 2µm contributed 20% of the total chlorophyll *a* on average. The mean daily production for the period May-October in 1996 and 1997 was estimated to be 410 and 420 mg carbon m^{-2} d^{-1}, respectively.

In the first year nutrients were added to the bay, the mean daily primary production increased to 580 mg carbon m^{-2} d^{-1}. However, the mean chlorophyll *a* content, 2.0 µg l^{-1}, was at the same level as the previous year, and the chlorophyll *a* content, in different size fractions, did not reveal any change in size distribution of the phytoplankton following the nutrient additions. The bacteria biomass and production remained at the same level during the investigation.

The growth rate of blue mussels in the period July-September 1997 and 1998 was in the range of 0.14–0.29 % d^{-1} at the different depths and locations. The highest daily increase in SH was recorded in Hopavågen in 1998, but it was not significantly higher than in 1997 or at the control station at Værnes. In the late autumn period (September-October), the growth rates varied from 0 to 0.07% d^{-1} at the sampling stations. The tissue content (wet and dry weight) at the end of the season was significantly higher in blue mussels in Hopavågen compared to mussels from the control station at Værnes.

The growth rate of scallops in Hopavågen increased from 0.16% d^{-1} in the period July-September in 1997 to 0.53% d^{-1} in 1998. During the latter year the recorded growth of SH of scallops in Hopavågen was significantly higher than the mean value for scallops grown in the fjord outside Hopavågen (0.44% d^{-1}). Also, between September and late October, the growth rate in the bay (about 0.20% d^{-1}) was much higher than in the previous year (0.04% d^{-1}). The tissue content (dry weight, ash free dry weight) in the scallops grown in Hopavågen was 2-4 times higher than in shells farmed at Værnes.

DISCUSSION

The addition of nutrients corresponding to an estimated annual supply of phosphorus and a molar ratio for N:Si:P of 15:5.4:1 caused a 46% increase in primary production in Hopavågen, compared to the pre-fertilization year. As the mean chlorophyll *a* content remained at the same level through the investigated period, the results indicate an increased turnover rate or increased grazing rate of the phytoplankton following the nutrient additions. The increased primary production in 1998 did not affect the SH growth of blue mussels *Mytilus edulis*. However, the shell content in mussels grown in Hopavågen was significantly higher than in mussels from the control station, which indicate that the increased production affected the somatic growth of the mussels. The SH of scallops *Pecten maximus* in the bay increased from 0.16% d^{-1} in 1997 to 0.53 % d^{-1} in 1998. The recorded growth of scallops in Hopavågen in 1998 was also significantly higher than for scallops outside the bay (0.44% d^{-1}). Even more pronounced was a 2-4 times higher content of shell tissue in the scallops grown in Hopavågen in 1998, compared to individuals from the control station at Værnes.

The results reveal that nutrients may be considered an important resource also in management of aquatic systems. However, dose-response experiments in marine waters with different water qualities are needed to establish a general knowledge of effects of nutrient supply on the productivity of different aquatic organisms and the environmental impact in a long-term perspective.